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Construction Engineering Research Laboratory

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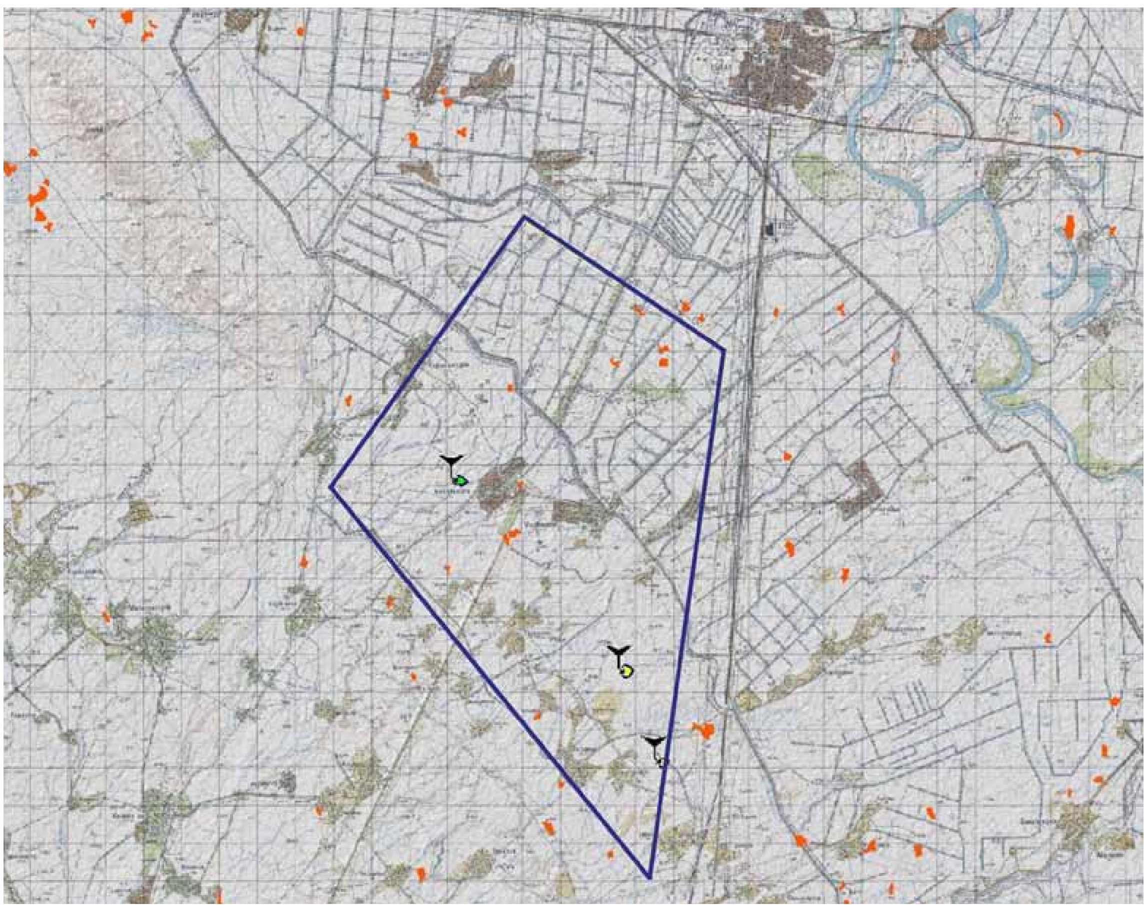
Operational Site Selection for Unmanned Aircraft

Scott Tweddale, Ted Fichtl, Sofya Tenenbaum, Dan Stouch, Charles Ehlschlaeger, and Kirk McGraw

June 2011



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Abstract: Selection of a suitable Operational Site (Op Site) for the launch and recovery of Unmanned Aircraft Systems (UAS) is critical to the success of any UAS mission. Operational Site Selection is a tactical mission task in which a UAS unit prepares a plan for the intended site and equipment locations before emplacing the system. To identify potentially suitable locations and eliminate unsuitable areas, the Op Site Selection process must first consider landcover, terrain, and specifications for one or more UAS platforms. To select the most optimal sites, the process must also consider additional dynamic factors pertaining to Mission, Enemy, Terrain & Weather, Troops & Support available, Time and Civil Considerations within the context of the current battle situation. This report describes an automated geoprocessing capability, or "engine," that has been developed to rapidly analyze spatially explicit data to identify potential Op Sites for multiple UAS platforms, and to rank their overall suitability.

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Preface

This research was conducted by the Construction Engineering Research Laboratory (ERDC-CERL) under "Data Analysis," under program element A855, "Topographical, Image Intel & Space"; Work Unit 332H4L, "Integrated Horizontal and Vertical Maneuver." The CERL technical monitor was Martin Savoie, Technical Director for Military Installations. The ERDC technical monitor was Michael Powers, Technical Director for Geospatial Research & Engineering.

This work was managed by the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The ERDC-CERL Principal Investigator (PI) was Scott A. Tweddale. User requirements for this work were developed by Charles River Analytics, Inc. (CRA) under contract W9132T-06-C-0040, "Operation and Technical Support for Geospatial Products to Enhance Unmanned Aerial Systems Effectiveness." Ted Fichtl, CRA, was subject matter expert and Dan Stouch, CRA, was project manager. Kirk McGraw is Program Manager of the Theater Assessment Program. William Meyer is Chief, Ecological Processes Branch (CN-N) of the Installations Division (CN), and Dr. John Bandy is Chief, CN. The Deputy Director of CERL is Dr. Kirankumar V. Topudurti, and the Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the US Army Engineer Research and Development Center (ERDC), US Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. Jeffery P. Holland.

1 Introduction

1.1 Background

Selection of a suitable Operational Site (Op Site) for the launch and recovery of Unmanned Aircraft Systems (UAS) is critical to the success of any UAS mission (Office of the Secretary of Defense 2009). Operational Site Selection (OSS) is a tactical mission task in which a UAS unit prepares a plan for the intended site and equipment locations before emplacing the system. To identify potentially suitable locations and eliminate unsuitable areas, the OSS process must first consider landcover, terrain, and specifications for one or more UAS platforms. To select the most optimal sites, the process must also consider additional dynamic factors pertaining to Mission, Enemy, Terrain & Weather, Troops & Support available, Time and Civil Considerations (METT-TC) within the context of the current battle situation.

The OSS engine is one of many engines developed or under development as part of the Battlespace Terrain Reasoning and Awareness Battle-Command (BTRA-BC) program. The BTRA-BC program is focused on development of software analytics designed to create actionable information and knowledge products that capture integrated terrain and weather effects in support of battlefield situational awareness and the decision making processes within Command and Control (C2) (ERDC TEC 2008). This work was undertaken to develop an automated geoprocessing capability, or "engine," to rapidly analyze spatially explicit data to identify potential Op Sites for multiple UAS platforms, and to rank their overall suitability.

1.2 Objectives

The objective of this research was to develop an automated geoprocessing capability, or engine, to rapidly analyze spatially explicit data to identify potential Op Sites for multiple UAS platforms and to rank their overall suitability.

1.3 Approach

An automated tool, or engine, was developed to rapidly analyze spatially explicit terrain and weather data to identify optimal potential Op Sites based on tactical and doctrinal considerations. The Op Site engine evaluates individual homogenous terrain units as determined by landcover, soil type, slope, and aspect. The individual terrain units are predetermined and delineated by a separate BTRA engine that analyzes standard Army geospatial data. The engine evaluates all terrain units within a user specified area of interest and identifies those units that could potentially be used as an Op Site based on a set of "non-negotiable" criteria. A suitability ranking or merit score is then calculated for each potential site using a set of "negotiable" criteria, with each criterion weighted to reflect its perceived importance. The engine is designed to work with the Shadow and Hunter UAS, but is adaptable to other UAS, including current and future platforms.

1.4 Mode of technology transfer

The OSS engine developed in this research will be transitioned to and implemented in the Commercial Joint Mapping Toolkit (ESRI and Northrop Grumman 2009, http://www.cjmtk.com), and therefore can be embedded within other Command, Control, Communications, and Computer Intelligence Surveillance, and Reconnaissance (C4ISR) systems. This report will be made accessible through the World Wide Web (WWW) at URL: http://www.cecer.army.mil

2 Methods

The OSS engine evaluates Digital Terrain Elevation Data (DTED), BTRA Complex data, and the Theater Geospatial Database (TGD) to identify potential Op Sites. The TGD data contains standard Army geospatial data at disparate spatial scales that supports traditional military mission areas. The BTRA Complex data is derived from a separate BTRA engine called the BTRA complex generator. The BTRA Complex generator combines TGD data, terrain slope and aspect data from a DTED, and weather grids to identify homogenous units of terrain. Each homogeneous terrain unit is defined as a BTRA Complex polygon within the BTRA Complex dataset. The OSS engine evaluates each terrain unit or BTRA Complex polygon as a potential Op Site. Although BTRA Complex polygons are derived from the TGD and DTED data by the BTRA complex generator, the OSS engine also refers directly to the TGD and DTED data for analysis.

The OSS engine creates Tactical Spatial Objects (TSOs) as output. A TSO contains a specific set of geospatial information necessary to support the military decision maker. A TSO typically incorporates information about the geographic, spatial, and temporal characteristics of the entity as reflected upon the operational context or mission directives. A TSO is stored in a geodatabase and consists of one or more feature classes and tables. In addition to a geospatial component, the TSO contains relationships to specific military operations, missions, and tasks — and may also have distinct relationships to various types and echelons of military operations.

A TSO is typically represented in two ways: as a graphic that is user understandable, and as a technical specification that is machine readable. The OSS engine produces Op Site TSO's at two different levels or "tiers." A Tier-1 Op Site TSO provides general support knowledge to aid in the selection of a suitable Op Site. A Tier-2 Op Site TSO allows the user to evaluate the most suitable potential Op Site for a given area and platform in support of a specific candidate course of action.

The following sections summarize the process used to evaluate criteria and rank polygons according to their suitability to support an Operation Site.

Table 1. Non-negotiable criteria for selection of potential Op Sites.

Criteria	Description
Size of proposed Op Site	The area is large enough to provide for an Op Site including all supporting equipment.
Terrain that allows landing at the required glide slope	The selected site has sufficient airspace for takeoff and landing. The site could be used as an emergency landing site if necessary.
Grade and cross slope	The runway direction and cross-slope specifications for the site are satisfactory.
Land use	Sites with incompatible land use are eliminated (e.g., open water, swamp).

2.1 Non-negotiable criteria

The following sections describe the four non-negotiable criteria to be evaluated for each potential Op Site (BTRA Complex polygon) (Table 1): (1) size, (2) glide path, (3) slope, and (4) land use.

2.1.1 Size

Potential Op Sites must be of sufficient size to accommodate the minimum footprint required for a runway and supporting equipment as summarized in Army doctrine (Department of the Army 2006). In addition to the total size criteria, an algorithm is also implemented to ensure that the minimum footprint size of an Op Site can be placed within the BTRA Complex polygon. Op Site placement is evaluated in 20 degree increments beginning at 0 (zero) degrees (North); each orientation that can be accommodated by the potential Op Site is recorded. A potential Op Site must be able to accommodate at least one orientation to satisfy the size requirement. This is necessary to eliminate BTRA Complex polygons that meet the minimum size criteria, but that would still be unable to accommodate an Op Site due to an irregular shape of the polygon. Minimum size and placement requirements are considered for multiple UAS platforms.

All existing runways are represented as polygons in the TGD. Therefore, existing runway polygons or polygons representing segments of existing runways are automatically identified as meeting size requirements even if their actual size does not meet the minimum size requirement.

2.1.2 Glide path

Potential Op Sites must be located in an area where glide path requirements are not restricted by surrounding topography in at least one orientation. Similar to Op site placement/orientation requirements, glide path restrictions are evaluated in 20 degree increments beginning at 0 (zero) degrees (North). A line-of-sight (LOS) algorithm is used to determine if glide path is restricted by surrounding topography using UAS platform specific approach and departure glide path requirements as defined by doctrine (Department of the Army 2006). A potential Op Site must be able to accommodate at least one orientation and coincident glide paths in both directions to satisfy the glide path requirement. Glide path requirements are UAS platform specific. Therefore, minimum glide path requirements are evaluated for multiple UAS platforms.

2.1.3 Slope

Mean slope must be <1 degree or 1.7 percent. The engine calculates mean slope for each BTRA Complex polygon based on the provided DTED for the Area of Analysis (AOA).

2.1.4 Land use

Potential Op Sites characterized as water features or other incompatible land uses are eliminated from consideration (Table 2). This includes all water features of sufficient size to be delineated as an individual BTRA Complex polygon with associated area. Potential obstacles delineated as line features in separate TGD data layers are evaluated separately under "Near-ground obstacles" in the negotiable criteria. Figure 1 shows the complete process for evaluating non-negotiable criteria. All potential Op Sites that do not meet the four "non-negotiable" criteria are eliminated from consideration.

Table 2. Incompatible land uses for Op Sites.

Land Use	BTRA Complex Feature Class Attribute
Lake/pond	LakeresA_F_CODE = BH080
Reservoir	LakeresA_F_CODE = BH130
Canal	WatrcrsA_F_CODE = BH020
Ditch	WatrcrsA_F_CODE = BH030
River/stream	WatrcrsA_F_CODE = BH140
Bog	SwampA_F_CODE = BH015
Marsh/swamp	SwampA_F_CODE = BH095
Land subject to inundation	InundA_F_CODE = BH090

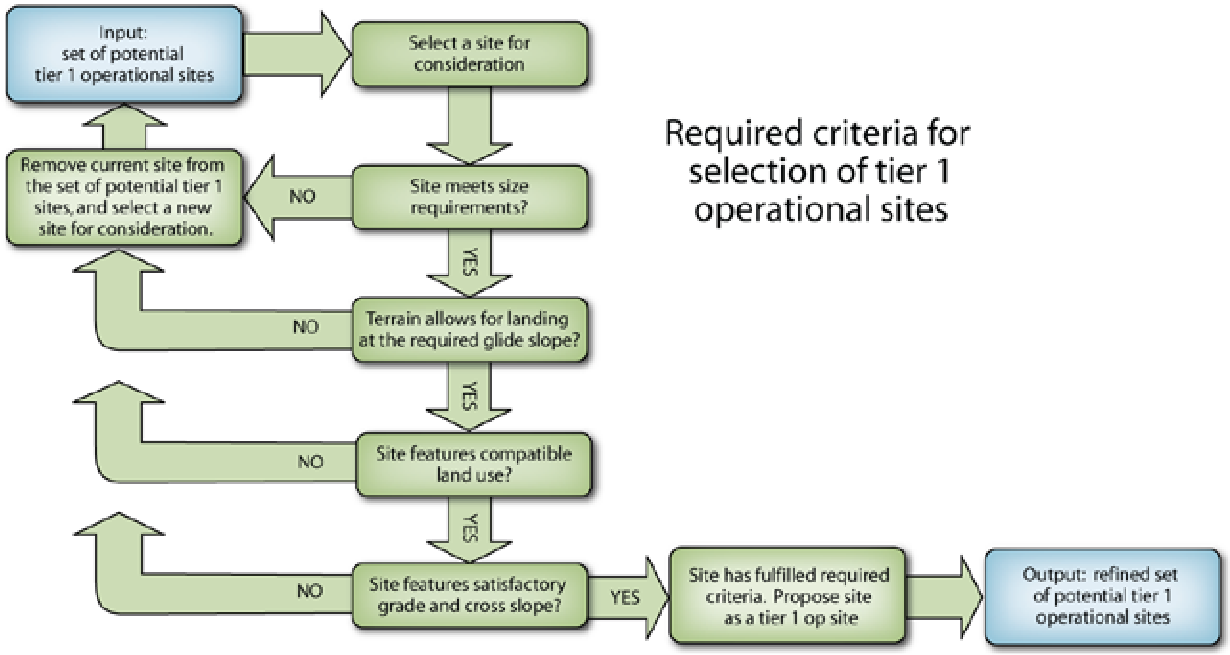

Figure 1. Final required criteria for a potential Op Site.

2.2 Negotiable criteria

All potential Op Sites that satisfy all of the non-negotiable criteria are evaluated against the "negotiable" criteria listed in Table 3.

Table 3. Desired criteria and tradeoffs.

Criteria	Weight	Sub-Ranking	Tradeoff
Site has existing infrastructure and is in good condition	50	50 = Existing Airfield 30 = Paved Road 20 = Unpaved Road	Risk of aircraft loss or damage
Site has little or no tall vegetation and vertical obstacles	15		Engineering effort to clear and prepare area
Historical weather/wind patterns at the site provide for consistent usability	10		Unpredictable usage pattern
Site has Line of Sight (LOS) to the Air Maneuver Network (AMN)	10	Percentage of AMN segments visible from Op Site * 10 (e.g., 80% visible = 0.8 * 10 = 8)	Poor performance or a need for an alternative Ground Control Station (GCS)
Site has few near-ground obstacles (e.g., brush, water)	5		Engineering effort to clear and prepare area
Soil composition allows for easy recovery	2.5		Risk of aircraft loss or damage

2.3 Existing infrastructure and condition

Potential Op Sites are evaluated based on the type and condition of infrastructure they contain according to the sub-ranking scheme listed in Table 4. The relatively high overall importance of the "Existing Infrastructure and Condition" criteria relative to all other criteria creates an effective bias towards roads, and an even more significant bias toward existing airfields. With all other criteria being equal, those BTRA Complex polygons containing some sort of existing airfield or road will receive the highest merit score.

Existing airfields provide the most desirable Op Site because they typically require minimal construction, because they provide ample room for supporting equipment, and because they are void of any vertical obstructions or glide path restrictions. In the absence of existing airfields, paved roads may be suitable for runways, assuming there are no vertical obstructions. Paved roads are more desirable than unpaved roads because they are likely to provide a smoother surface and because of the increased probability of airborne foreign object debris (FOD) from unpaved roads that can potentially damage UAS platforms.

2.4 Vertical obstacles

All potential Op Sites that are devoid of vertical obstacles are assigned a merit score of 15. Polygons containing existing airfields are automatically assigned a merit score of 15, since it is assumed that no vertical obstacles are present. A combination of attributes in the BTRA Complex feature class and multiple TGD feature classes are evaluated to determine whether vertical obstacles are present. Table 5 lists specific attributes that are considered vertical obstacles.

Table 4. Existing infrastructure and condition criteria and sub-rankings.

Condition	Sub-ranking	BTRA Complex Feature Class	Attributes
Existing Runway	50	BTRA Complex	RUNWAYA_F_CODE=GB055
Condition	**Sub-ranking**	**TGD Feature Class**	**Attributes**
Existing Paved Road	30	RoadL	f_code=AP030 and rst=1
Existing Unpaved Road	20	RoadL	f_code=AP030 and rst=2 or 3
No existing infrastructure	0	n/a	n/a

Table 5. Attributes considered vertical obstacles.

Obstacle	BTRA Complex Feature Class	Attribute
Trees	BTRA Complex	TREESA_F_CODE=EC030
Built up/urban	BTRA Complex	BUILTUPA_F_CODE=AL020
Obstacle	TGD Feature Class	Attribute
Power line	PowerL	f_code=AT030
Telephone/telegraph line	TeleL	f_code=AT060
Lift line	LiftL	f_code=AQ010

2.5 Prevailing wind

Potential Op Sites that can accommodate a runway and coincident glide path in the same orientation as prevailing wind are assigned a merit score of 10. The Op Site engine prompts the user for prevailing wind direction in 20 degree increments before creating the Tier-1 Op Site TSO. Runway orientations and coincident glide paths that can be accommodated for each potential Op Site are determined when evaluating non-negotiable criteria and are stored to evaluate against the prevailing wind pattern.

2.6 Line of sight

Potential Op Sites are evaluated with respect to Line of Sight (LOS) to the Air Maneuver Network (AMN). A critical aspect of Op Site selection is ensuring the site provides good transmitter coverage of the area of operations. Potential Op Sites that provide minimal LOS to segments of the AMN are less optimal and may require a supplemental ground control station (GCS). Therefore, potential Op Sites are assigned a merit score for LOS to AMN based on the percentage of total AMN segments at a given elevation that are completely contained within the transmitter viewshed. A LOS algorithm is used to determine the transmitter viewshed, which represents the total area of the AMN at a given altitude that is visible from the potential Op Site and takes into account the transmitter range associated with each platform as well as LOS with respect to topography. A value between 0 (zero) and 10 that is equal to the total percentage of AMN segments completely contained within the viewshed times 10 is assigned to each site (e.g., site with viewshed containing 87 percent of AMN segments = 0.87 x 10 = 8.7)

Due to computational requirements associated with calculating a viewshed for each potential Op Site, the LOS to AMN criterion is only calculated for the Tier-2 Op Site TSO. All other negotiable criteria are calculated for each potential Op Site that satisfies the non-negotiable criteria in the Tier-1 Op Site TSO.

2.7 Near-ground obstacles

In the absence of existing infrastructure that can be used as a runway, near ground obstacles must be removed or mitigated to create a suitable Op Site. All potential Op Sites that are void of near-ground obstacles are assigned a merit score of 5. Polygons containing existing runways or existing roads that are void of any interchanges, tunnels, or bridges are automatically assigned a merit score of 5, since it is assumed that any near-ground obstacles that may be present would not prevent the use of the runway or road. A combination of attributes in the BTRA Complex feature class and multiple TGD feature classes are evaluated to determine whether near-ground obstacles are present. Table 6 lists specific attributes that are considered near-ground obstacles.

Table 6. Attributes considered near-ground obstacles.

Name	BTRA Complex Feature Class	Attribute
Rice field Cropland	BTRA Complex	CROPA_F_CODE=BH135 CROPA_F_CODE=EA010
Grassland	BTRA Complex	GRASSA_F_CODE=EB010
Orchard/plantation Vineyard	BTRA Complex	ORCHARDA_F_CODE=EA040 ORCHARDA_F_CODE=EA050
Name	**TGD Feature Class**	**Attribute**
Aqueduct	AquedctL	f_code= BH010 AND (LOC=8 or LOC = 25)
Fence Wall	BarrierL	f_code=AL070 f_code=AL260
Bluff/cliff/escarpment	BluffL	f_code=DB010
Bridge/overpass/viaduct Bridge span Prepared raft/float bridge	BridgeL	f_code=AQ040 f_code=AQ045 f_code=AQ111
Causeway	CausewayL	f_code=AQ064
Spillway Dam/weir	DamL	f_code=BH165 f_code=BI020
Trench Cut line Embankment fill line	EmbankL	f_code=AH020 f_code=DB070 f_code=DB090
Hedgerow	HedgeL	f_code=EA020
Interchange	InterL	f_code=AP020
Ice cliff Crevice/crevasse Esker line Fault line Volcanic dike Gully/gorge	LandfrmL	f_code=BJ040 f_code=DB060 f_code=DB100 f_code=DB110 f_code=DB190 f_code=DB200

Name	TGD Feature Class	Attribute
Moat	MiscL	f_code=BH100
Pipeline/pipe	PipeL	f_code=AQ113 AND (LOC = 8 or LOC = 25)
Railroad track Railroad siding/spur	RailrdL	f_code=AN010 f_code=AN050
Revetment line	RevetmentL	f_code=GB050
Cart track	TrackL	f_code=AP010
Gate Barrier	TransL	f_code=AP040 f_code=AP041
Tree rows	TreesL	f_code=EC030
Tunnel	TunnelL	f_code=AQ130
Canal Ditch River/stream	WatercrsL	f_code=BH020 f_code=BH030 f_code=BH140

2.8 Soil composition

All potential Op Sites that do not have "Inorganic silts and very fine sand" soil composition are assigned a merit score of 2.5. Sandy soils are unacceptable because they do not provide sufficient ground density to support operations, and because they are more likely to produce airborne debris that can potentially damage UAS platforms. All potential Op sites containing existing infrastructure (airfields and roads) are automatically assigned a merit score of 2.5 because it is assumed that the existing infrastructure could support launch and recovery, even if the surrounding soil composition is unacceptable.

Figure 2 shows the complete process for evaluating negotiable criteria.

2.9 Tier-2 object generation

For Tier-2 object generation, an optimal set of Potential Op Sites identified in the Tier-1 TSO are selected based on user input, including the search area boundary, the specific platform to be used, the total number of sites desired, and the desired dispersion of potential sites. The LR_MERIT_SCORE attribute, which is calculated for all potential Op Sites in the Tier-1 TSO, is used to rank the sites. LR_MERIT_SCORE is calculated as the sum of merit scores for all negotiable criteria summarized in Table 3. If dispersion is selected as a desired criterion, both LR_MERIT_SCORE and a normalized distance score calculated using a dispersion algorithm are used to rank the sites.

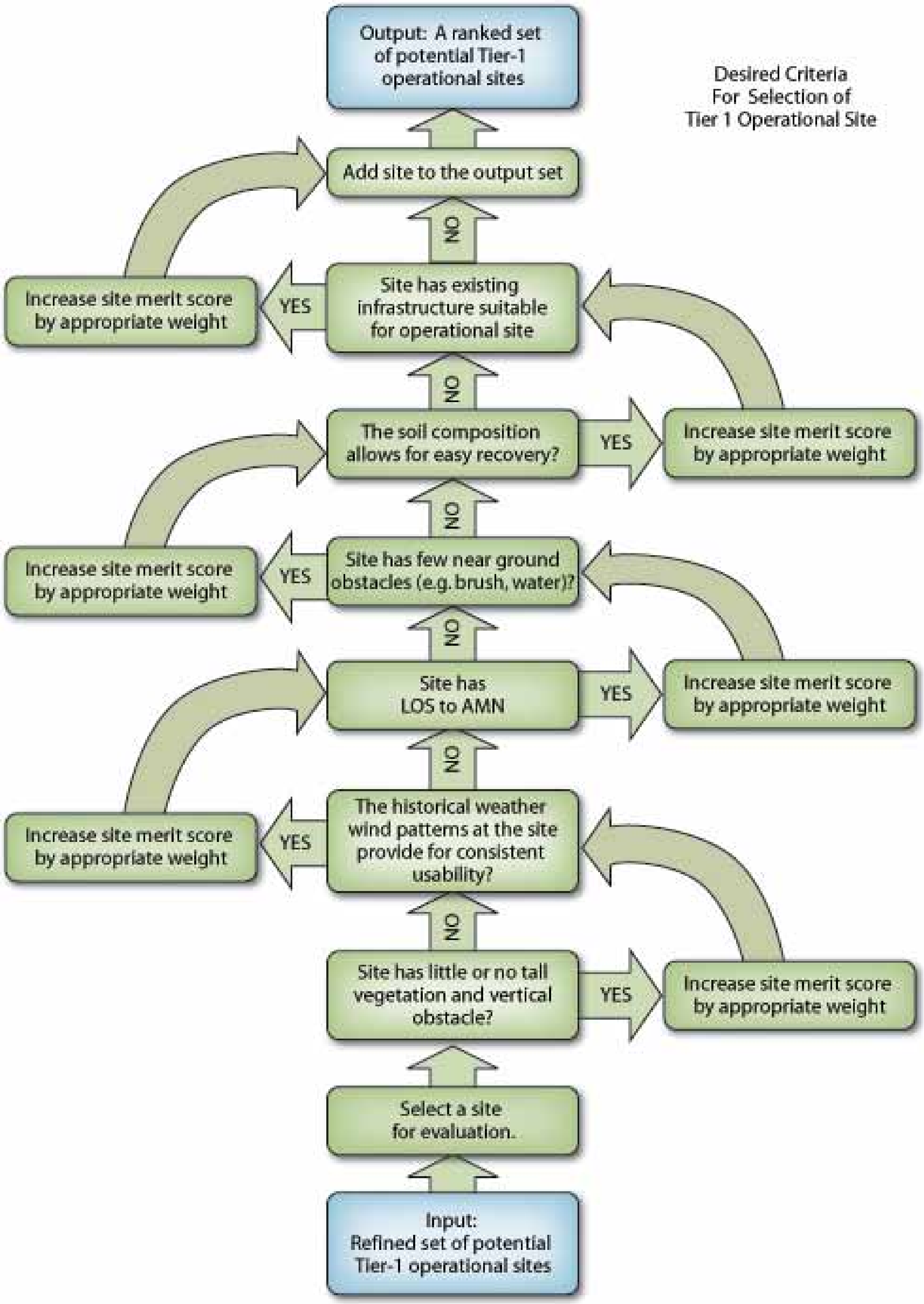

Figure 2. Final negotiable criteria for Tier-1 Op Site TSO.

The search area boundary provides a spatial constraint on the search. The platform selection serves as a filter to only consider potential Op Sites that can accommodate the selected platform. Potential Op Sites that can accommodate a specific platform can also accommodate less restrictive platforms, e.g., a site that can accommodate the Hunter UAS can also accommodate the Shadow UAS. The total number of sites identifies how many optimal Op Sites will be presented to the user for selection.

An optional dispersion algorithm that assesses the spatial pattern of potential Op Sites allows the user to specify that the top suitable OS sites are well dispersed across the search area. Without the dispersion algorithm, it is possible that the top sites identified in the Tier-2 TSO may be in close proximity to each other and therefore would not provide a set of spatially diverse sites. Dispersion of sites also reduces the likelihood that all sites will be determined unsuitable in the field due to unknown circumstances or missing and/or inaccurate geospatial data.

With or without the dispersion algorithm, the top ranked Op Site will be the same. If the user opts to include dispersion as a criterion, the dispersion algorithm uses both the LR_MERIT_SCORE and distance to the closest already chosen Op Site to determine the site that should be next on the list of optimal sites based on the following formulas:

$$DS_i = \sqrt{}(Dist_{ij} - min) / (max - min)$$

where:

DS_i = Normalized distance score of unchosen Op site i
$Dist_{ij}$ = Distance between Opsite i and closest chosen Op Site j
Min = Distance between closest potential Op Sites
Max = Distance between furthest potential Op Sites

The overall score for each potential Op Site is:

$$S_i = (DS_i * 0.75) + (C_i * 0.25)$$

where :

C_i = Original LR_MERIT_SCORE of unchosen Op Site i

3 Examples

3.1 Step 1 - Request Tier-1 TSO

The Op Site engine requires two inputs from the user before it can create the Tier-1 TSO: an Area_of_Analysis boundary and the prevailing wind direction. The Area_of_Analysis boundary is selected on the graphical display by either choosing a currently displayed boundary (delineated by a Graphic Control Measure [GCM]) or by drawing a new boundary. Prevailing wind direction is selected from a pick list of wind directions in 20 degree increments clockwise from North (Figure 3). Figure 3 also shows an Area_of_Analysis boundary named "AO_RUBY" that was drawn on the graphical display, and a (user selected) prevailing wind of 220 degrees.

3.2 Step 2 - Request Tier-2 TSO

The Op Site engine requires four user inputs before it can create the Tier-2 TSO: (1) a Search_Area boundary, (2) platform, (3) number of desired sites, and (4) an optional selection to include dispersion of sites as a criterion. The process is similar to that of selecting the Area_of_Analysis boundary as input to creation of the Tier-1 TSO; the Search_Area boundary is selected on the graphical display by either choosing a currently displayed boundary (delineated by a GCM) or by drawing a new boundary. Once an Area_of_Analysis boundary is defined, the engine will discover the corresponding Tier-1 TSO from which it will identify optimal sites.

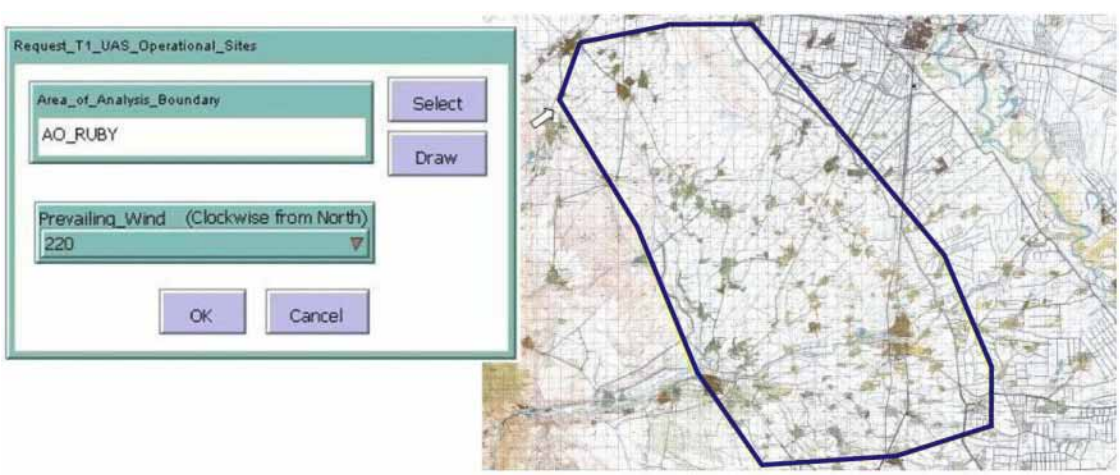

Figure 3. User interface for creation of Tier-1 TSO.

Figure 4 shows the menu with which the user selects the platform and number of sites from a pick list, and turns the dispersion criterion ON or OFF. Figure 4 also shows an Area_of_Analysis boundary named "TAA_PANDORA" that was drawn on the graphical display. In this example, the user has requested the top three optimal sites in this search area that can accommodate the MQ-5 Hunter platform. The dispersion algorithm has been set to OFF, and therefore, distance between sites will not be considered when identifying the top three sites.

3.3 Example Tier-2 Op Site TSO output

Tier-2 object generation returns a set of Tier-2 Op Sites for selection by the commander or use by other tools, such as the UAS route planning engine. Unlike the Tier-1 TSO, these sites are presented graphically in the operational planning environment as GCMs (Figure 5). In this example, the top three UAS Op Sites within the search area boundary that can accommodate the MQ-5 Hunter platform are identified with push-pin icons. Other potential Op Sites that were considered but that were not ranked in the top three are displayed in orange.

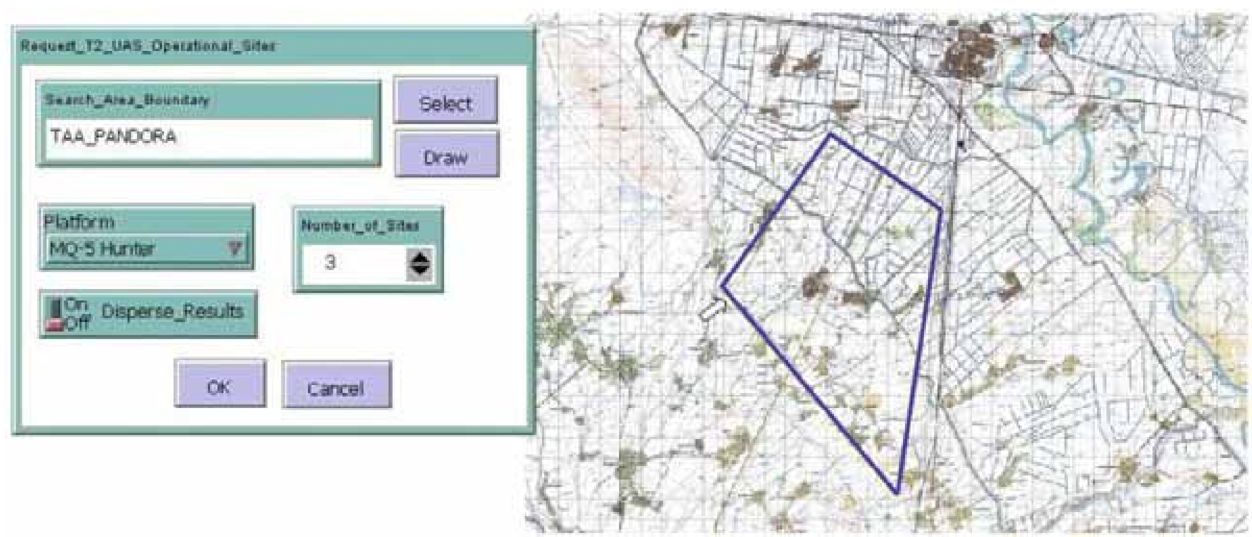

Figure 4. User interface for creation of Tier-2 TSO.

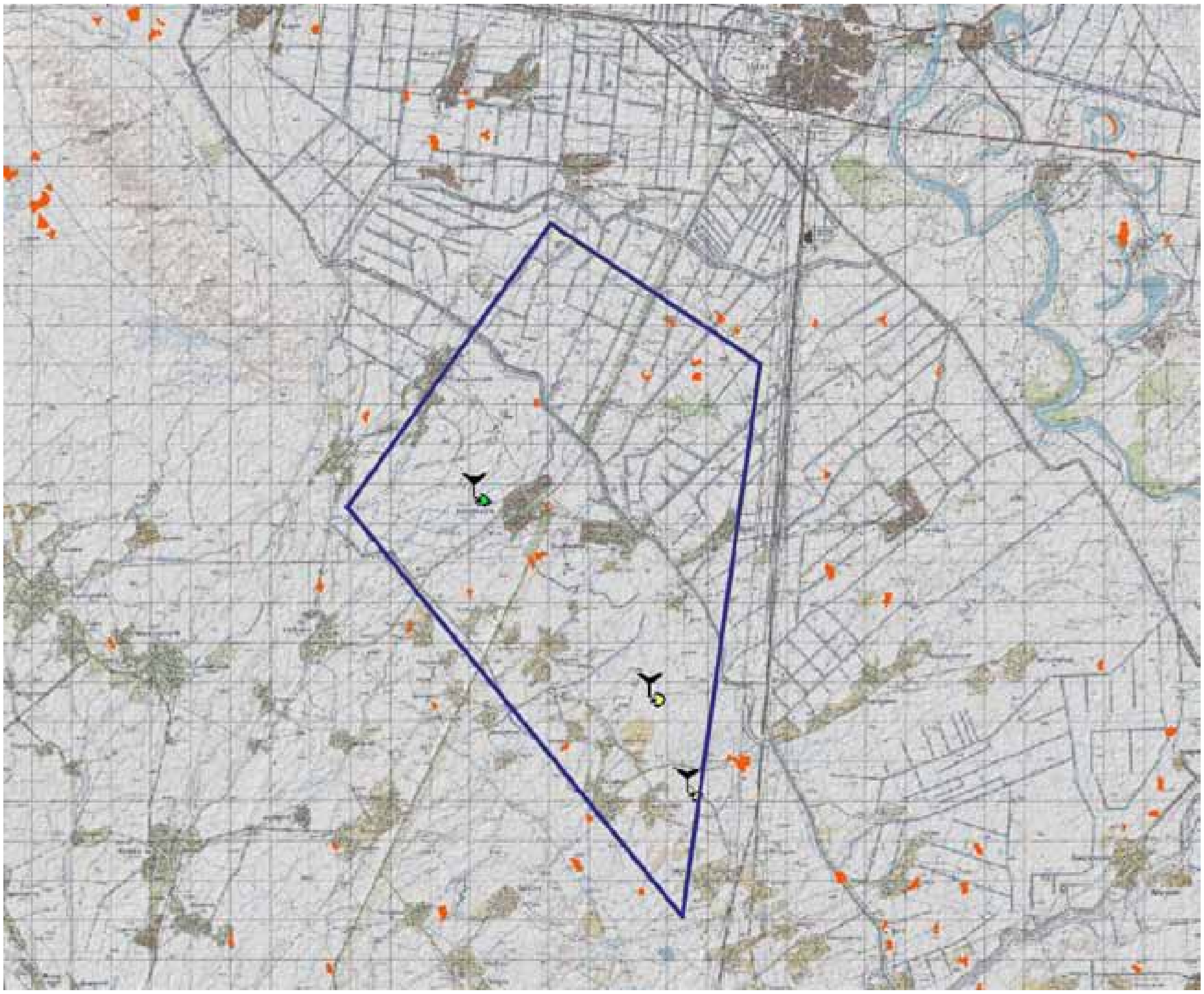

Figure 5. Example Tier-2 Op Site TSO output

3.4 Input/output model

3.4.1 Inputs

The Op Site engine accepts input from a variety of sources, including other BTRA-BC engines, existing BTRA-BC data (BTRA Complex, DTED, and TGD feature classes), existing literature, Army doctrine, and user input. Table 7 lists these inputs.

Table 7. Inputs to Op Site engine

Input	Source	Method	Planning Consideration	Objective
Air maneuver network	AMN Engine	Transmitter Viewshed Algorithm	Communication	Accessible
Area of analysis boundary (Tier 1)	User	Draw/Select	Spatial Constraint	n/a
AquedctL	TGD	Engine discovers	Near ground obstruction	Suitable
BarrierL	TGD	Engine discovers	Near ground obstruction	Suitable
BluffL	TGD	Engine discovers	Near ground obstruction	Suitable
BridgeL	TGD	Engine discovers	Near ground obstruction	Suitable
BTRA complex	Tier 0 Engine	Engine discovers	Various	Suitable
CausewayL	TGD	Engine discovers	Near ground obstruction	Suitable
DamL	TGD	Engine discovers	Near ground obstruction	Suitable
Dispersion	User	Select ON/OFF	Dispersion	Suitable
DTED	Tier 0 Engine	Engine discovers	Ground Slope/Glide Path/Transmitter LOS	Suitable
EmbankL	TGD	Engine discovers	Near ground obstruction	Suitable
HedgeL	TGD	Engine discovers	Near ground obstruction	Suitable
InterL	TGD	Engine discovers	Near ground obstruction	Suitable
LandfrmL	TGD	Engine discovers	Near ground obstruction	Suitable
LiftL	TGD	Engine discovers	Vertical obstruction	Suitable
MiscL	TGD	Engine discovers	Near ground obstruction	Suitable
Number of sites	User	Pick list	n/a	n/a
PipeL	TGD	Engine discovers	Near ground obstruction	Suitable
Platform	User	Pick list	Platform specific require-ments	Suitable
Platform parameters	Doctrine	Engine discovers	Platform specs	Suitable
PowerL	TGD	Engine discovers	Vertical obstruction	Suitable
Prevailing wind	User	Pick List	Historical Weather	Suitable
RailrdL	TGD	Engine discovers	Near ground obstruction	Suitable
RevetmentL	TGD	Engine discovers	Near ground obstruction	Suitable
RoadL	TGD	Engine discovers	Existing Infrastructure	Suitable
Search area boundary (Tier-2)	User	Draw/Select	Spatial Constraint	n/a
TeleL	TGD	Engine discovers	Vertical obstruction	Suitable
TrackL	TGD	Engine discovers	Near ground obstruction	Suitable
TransL	TGD	Engine discovers	Near ground obstruction	Suitable
TreesL	TGD	Engine discovers	Near ground obstruction	Suitable
TunnelL	TGD	Engine discovers	Near ground obstruction	Suitable
WatercrsL	TGD	Engine discovers	Near ground obstruction	Suitable

3.4.2 Outputs

The Tier-1 Op Site engine retains some of the attributes from the BTRA Complex feature class and appends additional attributes to create the Tier-1 Op Site TSO. Some original attributes in the BTRA Complex feature class that are not relevant to creation of the Tier-1 Op Site TSO are removed, while new attributes are added to store new information created by the engine. Table 8 lists and describes Tier-1 and Tier-2 TSO attributes created by the Op Site engine.

A Platform Evaluation Table is also created to store results from platform specific evaluations of each potential Op Site. This table has a one-to-many relationship with the Tier-1 Centroid and Tier-1 Polygon TSO feature classes. For every polygon (and every centroid) in the feature classes, there are individual records for each platform in the Platform Evaluation Table. Table 9 lists specific attributes in this table.

Table 8. Tier-1 and Tier-2 TSO attributes created by the Op Site engine.

Name	Data Type	Range	Uses
ELEVATION_LOS	Float	0-10	% of AMN in transmitter viewshed * 10
GRND_AQDUCT	Short	0, 1	0 = Above ground aqueduct present
GRND_BARRIER	Short	0, 1	0 = Fence or wall present
GRND_BLUFF	Short	0, 1	0 = Bluff present
GRND_BRDGE	Short	0, 1	0 = Bridge present
GRND_CSWAY	Short	0, 1	0 = Causeway present
GRND_DAM	Short	0, 1	0 = Dam present
GRND_EMBANK	Short	0, 1	0 = Embankment present
GRND_GROUNDCOVER	Short	0, 1	0 = Groundcover obstruction present
GRND_HEDGE	Short	0, 1	0 = Hedge row present
GRND_INTER	Short	0, 1	0 = Interchange present
GRND_LANDFRM	Short	0, 1	0 = Landform present
GRND_MISC	Short	0, 1	0 = Moat present
GRND_PIPEL	Short	0, 1	0 = Above ground pipeline present
GRND_RAIL	Short	0, 1	0 = Railroad track present
GRND_REVET	Short	0, 1	0 = Revetment line present
GRND_CART	Short	0, 1	0 = Cart track line present
GRND_TRANS	Short	0, 1	0 = Gate or barrier present
GRND_TREE	Short	0, 1	0 = Tree line present
GRND_TUNNEL	Short	0, 1	0 = Tunnel present
GRND_WATRCRS	Short	0, 1	0 = Water crossing line present

Name	Data Type	Range	Uses
INFRA_CONDITION	Short	0, 20, 30, 50	0 = no existing infrastructure 20 = unpaved road present 30 = paved road present 50 = runway present
LR_MERIT_SCORE	Float	0-92.5	INFRA_CONDITION + OBST_VERT + ELEVATION_LOS + OBST_GROUND + SOIL_COMP + MERIT SCORE (from "merit_score" in corresponding platform evaluation table, See Table 9.)
MEAN_SLOPE	Short	1, 2	1= slope is acceptable for Op Site
OBST_GROUND	Short	0, 5	5 = site is void of near-ground obstacles
OBST_VERTICAL	Short	0, 15	15 = site is void of vertical obstacles
SOIL_COMP	Float	0, 2.5	2.5 = soil composition is not "inorganic silts and very find sand"
VERT_LIFT	Short	0, 1	0 = Vertical lift is present
VERT_POWER	Short	0, 1	0 = Power line is present
VERT_TELE	Short	0, 1	0 = Telephone/Telegraph line is present

Table 9. Platform evaluation table attributes created by the Op Site engine.

Name	Data Type	Range	Uses
tsoid	GUID		Link to corresponding Tier-1 feature classes (or sets)
feat_id	long		Foreign key to feat_id primary key in Tier-1 feature class
platform_name	text		Platform name
nonneg_yn	short	0, 1	1 = platform satisfies required criteria
runways	long	0-1023	Coded bit-map string indicating which runway orientations can be accommodated
glidepath_yn	short	0, 1	1 = unrestricted glide path exists
pwd	short	0-360	Prevailing wind direction (20 degree increments)
pwd_yn	short	0, 1	1 = unrestricted glide path exists at orientation of prevailing wind
merit_score	short	0, 10	10 = unrestricted glide path exists at orientation of prevailing wind

4 Summary

This work has developed an automated geoprocessing capability, or engine, to rapidly analyze spatially explicit data to identify potential Op Sites for multiple UAS platforms, and to rank their overall suitability. This engine provides a capability that will allow commanders to make better informed decisions on the selection of Op Site locations. In addition, this capability provides information to a suite of additional analytical engines within the Battlespace Terrain Reasoning and Awareness - Battle Command (BTRA-BC) program.

These engines are designed to create actionable information and knowledge products that capture integrated terrain and weather effects in support of battlefield situational awareness and the decisionmaking processes within the Command and Control (C2) process. The OSS engine, along with other BTRA engines, will be transitioned to the Commercial Joint Mapping Toolkit (CJMTK), and will be embedded within other Command, Control, Communications, and Computer Intelligence Surveillance, and Reconnaissance (C4ISR) systems.

Acronyms and Abbreviations

Term	Spellout
AMN	Air Maneuver Network
ANSI	American National Standards Institute
AOA	Area of Analysis (AOA)
BTRA	Battlespace Terrain Reasoning and Awareness
CERL	Construction Engineering Research Laboratory
CJMTK	Commercial Joint Mapping Toolkit
CRA	Charles River Analytics, Inc.
DC	District of Columbia
DTED	Digital Terrain Elevation Data
ERDC	Engineer Research and Development Center
ESRI	Environmental Systems Research Institute, Inc.
FM	Field Manual
FOD	Foreign Object Debris
GCM	Graphic Control Measure
GCS	Ground Control Station
JGES	Joint Geospatial Enterprise Services
LOS	Line of Sight
METT-TC	Mission, Enemy, Terrain & Weather, Troops & Support available, Time and Civil Considerations
NSN	National Supply Number
OMB	Office of Management and Budget
OS	Op Site
OSD	Office of the Secretary of Defense
OSS	Operational Site Selection
PI	Principal Investigator
SAR	Same as Report
TEC	Topographic Engineering Center
TGD	Theater Geospatial Database
TR	Technical Report
TSO	Tactical Spatial Object
UAS	Unmanned Aerial System
URL	Universal Resource Locator
US	United States
WWW	World Wide Web

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14. ABSTRACT
Selection of a suitable Operational Site (Op Site) for the launch and recovery of Unmanned Aircraft Systems (UAS) is critical to the success of any UAS mission. Op Site Selection is a tactical mission task in which a UAS unit prepares a plan for the intended site and equipment locations before emplacing the system. To identify potentially suitable locations and eliminate unsuitable areas, the Operational Site Selection process must first consider landcover, terrain, and specifications for one or more UAS platforms. To select the most optimal sites, the process must also consider additional dynamic factors pertaining to Mission, Enemy, Terrain & Weather, Troops & Support available, Time and Civil Considerations within the context of the current battle situation. This report describes an automated geoprocessing capability, or "engine," that has been developed to rapidly analyze spatially explicit data to identify potential Op Sites for multiple UAS platforms, and to rank their overall suitability.

15. SUBJECT TERMS
geospatial data, spatial data analysis, unmanned aircraft systems (UAS)

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